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CEEFAX:
measurement techniques

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CEEFAX: MEASUREMENT TECHNIQUES

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Summary

New techniques have been developed to measure the characteristics of a CEEFAX waveform and to assess the performance of a CEEFAX installation.

Methods are discussed for measuring the normal CEEFAX waveform in terms of its level and other factors which affect the CEEFAX service at a receiving installation. Techniques are also described for assessing the CEEFAX performance of signal paths, using special test signals.

The techniques described require further development to simplify, and possibly automate, the procedures.

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CEEFAX: MEASUREMENT TECHNIQUES

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1. Introduction

The CEEFAX information service is provided by transmitting additional signals in the television field-blanking interval. These signals are of a digital nature and are coded to form a binary waveform, the bit-rate being 6·9375 Mbit/s. At present, this waveform is generated at the Television Centre (London) and transmitted during previously unoccupied television lines (17, 18 and 330 and 331).

To maintain a high technical standard for this signal it is necessary to monitor the CEEFAX waveform at points in the distribution chain. Further measurements must be made to check that the performances of transmitters or other parts of the signal chain are adequate to give a good CEEFAX service.

To some extent, the digital CEEFAX signal is more rugged than the analogue television signal it accompanies. One property of a digital signal is that if, in spite of distortion and noise, the original data can be recovered without error, data-regenerators can be used to 'renew' the signal. However, the number of such data-regenerators that can be installed is limited by the cost and, therefore, measurements of the CEEFAX waveform have been made to identify where a limited number of regenerators would be most effectively deployed.

New monitoring techniques are required for the CEEFAX signal. The digital nature of the signal makes the critical parameters of a transmission system different from those relating to an analogue television signal. Moreover, when the CEEFAX waveform is regenerated at points in the networking and transmitting chain it is important to monitor the CEEFAX signal separately; it is not possible to use signals such as the I.T.S.* as they are not normally originated at the same point as a regenerated CEEFAX signal.

In some cases it may be desirable to measure the CEEFAX performance of individual elements of a signal chain. This would apply to television signal processing equipment where special signals can be applied at the input and measurements made using suitable apparatus connected to the output.

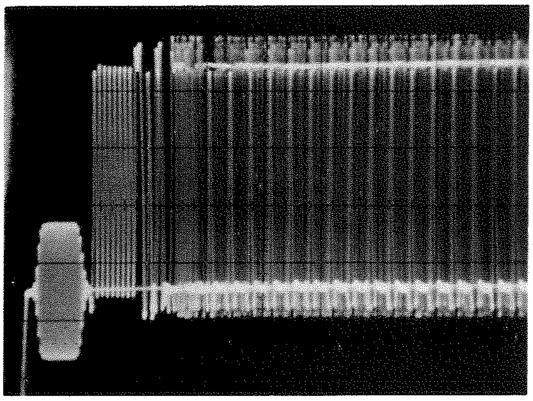
This report describes techniques for measuring the CEEFAX waveform and the CEEFAX-signal characteristics of individual systems. In addition criteria for assessing the quality of a received CEEFAX service are discussed.

2. Measuring data level

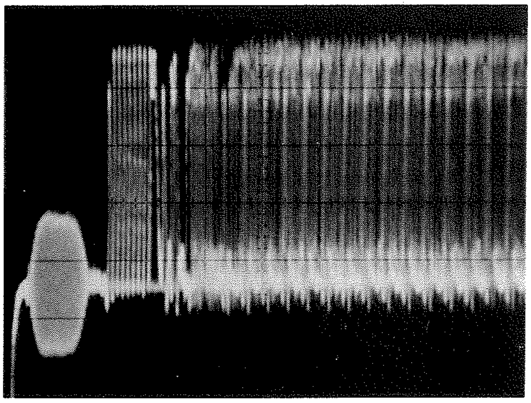
2.1. General

The Teletext Specification,[1] which applies for CEEFAX, defines the data level in terms of the television-signal black and white levels. Logical 0 corresponds to black level and logical 1 to 66% of white level (i.e. 0·462V data with a standard-level television signal). CEEFAX sources are aligned to generate data at this level. Thereafter, the data level will be required to be measured directly.

Unfortunately, the CEEFAX waveform normally contains overshoots because the System I television video bandwidth of 5·5 MHz does not permit the data to be transmitted as raised-cosine shaped pulses. Moreover, the amplitude of the overshoots is affected by quite small amounts of amplitude and group-delay distortion. Hence the level



(*a*)



(*b*)

Fig. 1 - CEEFAX waveforms

(*a*) Close to source* (*b*) At a remote point in the network

* note that data timing is non-standard

of the data waveform cannot be measured in terms of its peak-to-peak value and techniques are required to enable the height of a notional CEEFAX bar (a sequence of logical '0's followed by a sequence of logical '1's) to be measured directly from the CEEFAX waveform when a typical magazine of CEEFAX information is being transmitted.

---

* Insertion Test Signal.

2.2. Direct measurement from an oscilloscope display

In some cases it is possible to measure the data level by displaying the CEEFAX waveform on an oscilloscope and observing the denser regions of the traces. Fig. 1 shows photographs of the oscilloscope display of a CEEFAX waveform, first, close to the source and, secondly, at a remote point in the distribution network. From the first, it would be relatively easy to estimate the data level. In the second case, added noise and distortion make the data levels less distinct and it is not possible to estimate, with any accuracy, the data level from this photograph.

A more reliable measurement can be made by observing the levels of special sequences including frequent strings of '0's and '1's. A test page of the CEEFAX magazine currently includes a 'clock-cracker' sequence on about half of the rows; this consists of repeated character pairs 01111111, 11111110 on alternate rows and 10000000, 00000001 on the other rows. These sequences are primarily intended to test data-clock recovery circuits in a decoder but the long strings of '1's and '0's can also be used for measuring the data level. However such measurements are time consuming and difficult to make because the test-page is only one of the 100 possible pages of a magazine.

2.3. The use of a filter to remove the overshoots

Measurement of the CEEFAX data level can be simplified by using a low-pass filter which removes the overshoots from the waveform. A convenient filter has been found to be one whose response to a unit step is of approximately raised-cosine shape and rises to the full amplitude of the step in four CEEFAX bit periods (Fig. 2). The design details, of a fourth-order Gaussian filter which is suitable, are given in Fig. 3. The low-frequency insertion loss of this filter is negligible.

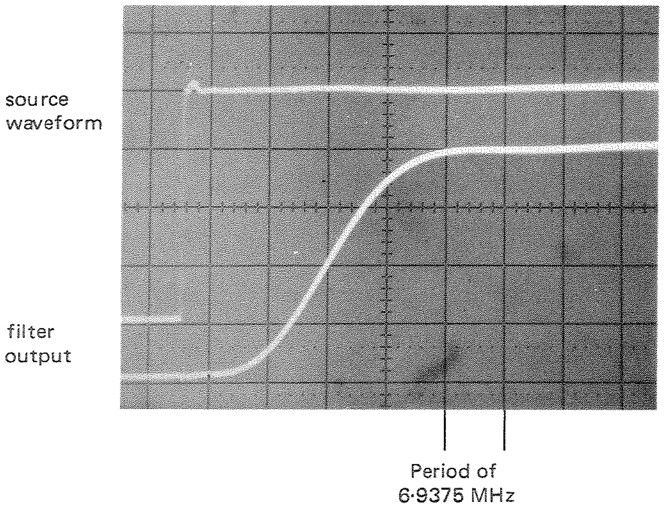


Fig. 2 - Step response of measurement filter

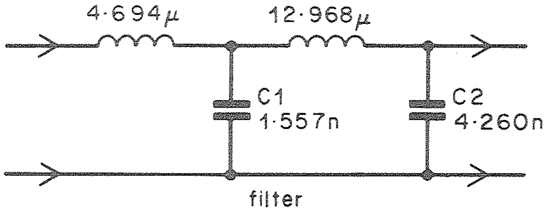


Fig. 3 - Circuit of 75Ω low-pass filter to remove overshoots from a CEEFAX data waveform

The effect of the filter on typical CEEFAX waveforms is illustrated in Fig. 4. This shows that the peak-to-peak magnitude of the waveform at the output of the filter is substantially independent of any overshoots in the original waveform and can be taken as a meaningful measurement of the level of the CEEFAX waveform. The measurement can be related to the level of the normal television waveform by observing the amplitude of the I.T.S. bar at the output of the same filter.

A further measurement, which can be made using the same filter, relates to the mean level of the clock run-in sequence at the beginning of each CEEFAX line. The

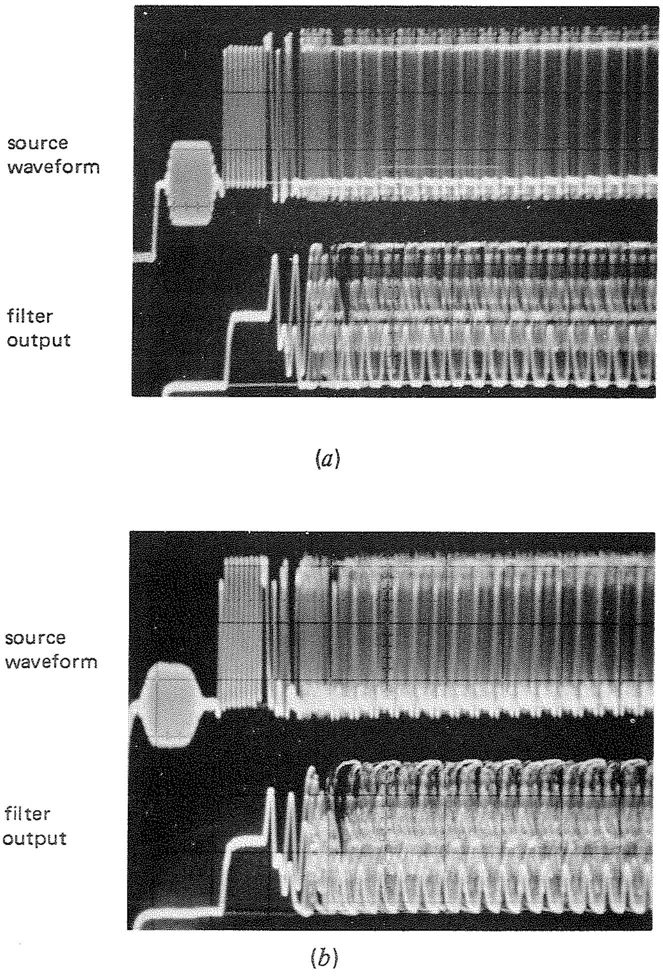


Fig. 4 - Effect of filter on typical CEEFAX waveforms

filter attenuates this half clock-rate frequency: indeed an ideal raised-cosine filter would have zero response at this frequency. Measurement of the mean level of the clock run-in sequence is helpful in quantifying non-linear distortions, including quadrature distortion.

The mean, and logical '0' and '1' levels obtained using such a filter may be used in the data recovery circuit of a CEEFAX decoder.

3. Measurements using a CEEFAX decoder

Using a CEEFAX decoder of calibrated performance, measurements can be made of impairments affecting the CEEFAX waveform. First, checks can be made that the data can be correctly recovered from the CEEFAX waveform. Secondly, measurements can be made of the amount of random noise that can be added to the waveform, at the input of the decoder, before errors are introduced in the decoded output. Such tests have been used extensively in CEEFAX field trials both in the UK[2] and Bavaria.[3]

Both techniques mentioned above require that errors are observed or counted at the output of a decoder. Because CEEFAX characters are parity protected,[1] single bit errors are normally arranged to cause spaces in the display where a character would otherwise have appeared. Further, with some additional equipment connected to a decoder, errors can be monitored, for the entire data stream, by checking the parity of the eight-bit character codes received.

It must then be decided whether a particular error rate is significant; Table 1 shows how rates of occurrence of errors can be judged against four criteria. These criteria are also useful reference points in measuring system performances when no means of counting bit errors is available.

Criterion A is clearly the most stringent and signals can only be tested against this using a decoder which incorporates special error-monitoring facilities. Criteria B and C can be applied using a normal decoder and a received CEEFAX service should be judged against these. Where pages are re-transmitted frequently, it is suggested that a service in which no errors remain after two writes of one page is adequate. In other cases the more stringent criterion of no visible errors in each of 3 consecutive new acquisitions of one page would define an almost perfect reception of CEEFAX. Criteria C and D are relatively easy to measure and have been found particularly useful in assessing margins of performance by attenuating the r.f. input signal to a receiver, thus increasing the noise content of the detected video signal, until one of these criteria is just met.[2,3]

As tests of the kind outlined above test the decoder as much as the signal, they can only be used where the particular decoder has been carefully aligned and calibrated and is known to have a stable performance. As several different techniques of data and clock recovery are used in decoders, these tests are of more use in giving relative results with the same equipment and different signals, rather than absolute results.

4. CEEFAX eye

4.1. General

Measurements to quantify any impairments of the CEEFAX waveform should relate to the ease with which the

TABLE 1

Criteria for assessing CEEFAX reception

Criterion	Approximate* character code error probability	Equivalent* approximate bit error probability
A) No errors received in 10 seconds for entire data stream	$1{\cdot}2 \times 10^{-5}$	$1{\cdot}6 \times 10^{-6}$
B) No visible errors in each of 3 consecutive new acquisitions of one page	$1{\cdot}7 \times 10^{-4}$	$2{\cdot}2 \times 10^{-5}$
C) No errors remaining after two writes of one page	$2{\cdot}3 \times 10^{-2}$	$2{\cdot}8 \times 10^{-3}$
D) About half of the characters correct for each new acquisition of one page	0·5	4×10^{-2}

* The visibility of errors at a given error rate depends on the nature of the pages. When parity failures are displayed as spaces a page with many spaces may appear to have a lower error rate. A page with many control characters may appear to have a higher error rate as the display mode may be wrong for a large part of a row following a single error.

original sequence of logical '1's and '0's can be recovered. In this section the action of the data detection circuits of a decoder is discussed and a parameter, known as eye-height, is defined.

4.2. Decoding the CEEFAX waveform to give logical '1's and '0's

In a typical CEEFAX decoder the voltage of the input waveform is compared with a reference voltage set (either manually or automatically) midway in the total voltage range excursed by the input waveform. A level comparator may then be used to slice the waveform, i.e. to subject it to severe amplitude limiting. Timing information is usually extracted by applying impulses, generated at the transitions of the sliced waveform, to a resonant circuit tuned to the data bit-rate. The timing information is then phase shifted and used to strobe, or sample, the sliced CEEFAX waveform at instants in the centre of each bit interval, where the '1' and '0' logic levels of the sliced waveform are most likely to be correct.

In these circumstances, the most important quality of the received CEEFAX waveform is the voltage difference between the lowest level of a logic '1' and the highest level of a logic '0', measured at the sampling instants. For example, if added noise or signal distortion causes the level of a '1' to be received as a voltage lower than the reference voltage it will be erroneously interpreted as a '0'.

4.3. CEEFAX eye pattern

To provide a measurement of the CEEFAX waveform which relates directly to the readiness with which it can be decoded in the presence of noise or other impairments, it is necessary to measure how close the waveform approaches the reference voltage at a sampling instant. The peak-to-peak magnitude of the CEEFAX waveform is also important in assessing the degree that multipath may affect the ease of decoding the data. Measurements of this kind may be made from an eye pattern display of the CEEFAX waveform.

An eye pattern is formed from a CEEFAX waveform by sub-dividing the waveform into sections equal in length to one data bit interval and disposed symmetrically about the centre of each interval. The time axes of the sections of the waveform are then superimposed which results in an oscilloscope display whose shape resembles that of an eye.

The boundaries of a CEEFAX eye pattern are shown in Fig. 5. Parameters which are important in assessing the CEEFAX waveform are the height at the centre of the eye, the symmetry of the eye shape and the peak-to-peak data magnitude.

4.4. Definition of eye-height

The eye-height (h in Fig. 5) of a CEEFAX waveform is the difference between the highest level corresponding to logical '0' and the lowest level corresponding to logical '1', measured in the centre of the bit cells (i.e. midway between the average times at which transitions may occur from one logic level to the other). This measurement should then be normalised relative to the data level (see Section 2).

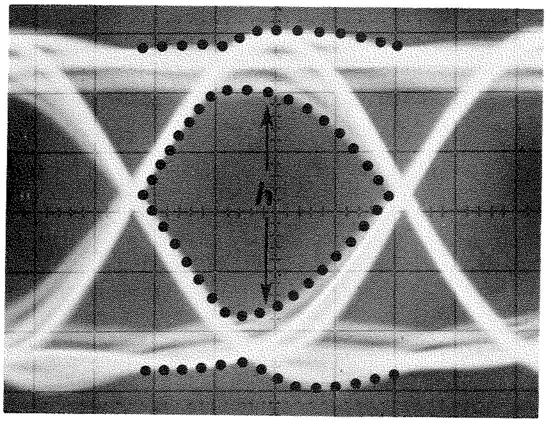


Fig. 5 - A CEEFAX eye pattern

•••••• boundary h eye-height

5. Display and measurement of the eye of a CEEFAX waveform

5.1. General

The eye pattern of a CEEFAX waveform cannot easily be displayed using the conventional horizontal deflection facilities of an oscilloscope; CEEFAX data is transmitted in relatively short bursts and the normal flyback time of an oscilloscope is such that only a few traces would be made during each of the two television lines per field containing a CEEFAX waveform.

Circuits enabling CEEFAX eye-pattern displays to be provided are described below.

5.2. Oscilloscope display of CEEFAX eye pattern

5.2.1. Principle

Equipment has been developed which derives, from the CEEFAX waveform, horizontal deflection and trace intensity modulation waveforms to produce an eye pattern on an oscilloscope. It includes data-slice and bit-synchronous clock-generation circuits similar to those used in a CEEFAX decoder.

The horizontal deflection waveform is a sine wave at half CEEFAX bit-rate rather than a linear ramp signal; this avoids the need to use an oscilloscope whose horizontal amplifier has a good amplitude and phase characteristic at frequencies higher than the normal video band. However, it is necessary to be cautious when interpreting the display. Any horizontal asymmetry of the data eye is lost because successive eyes are superimposed with their time axes reversed. Hence eye measurements are only valid in the centre of the bit cell. Facilities are therefore provided to enable the phase of the horizontal deflection signal to be adjusted so that the centres of bit cells are displayed in coincidence.

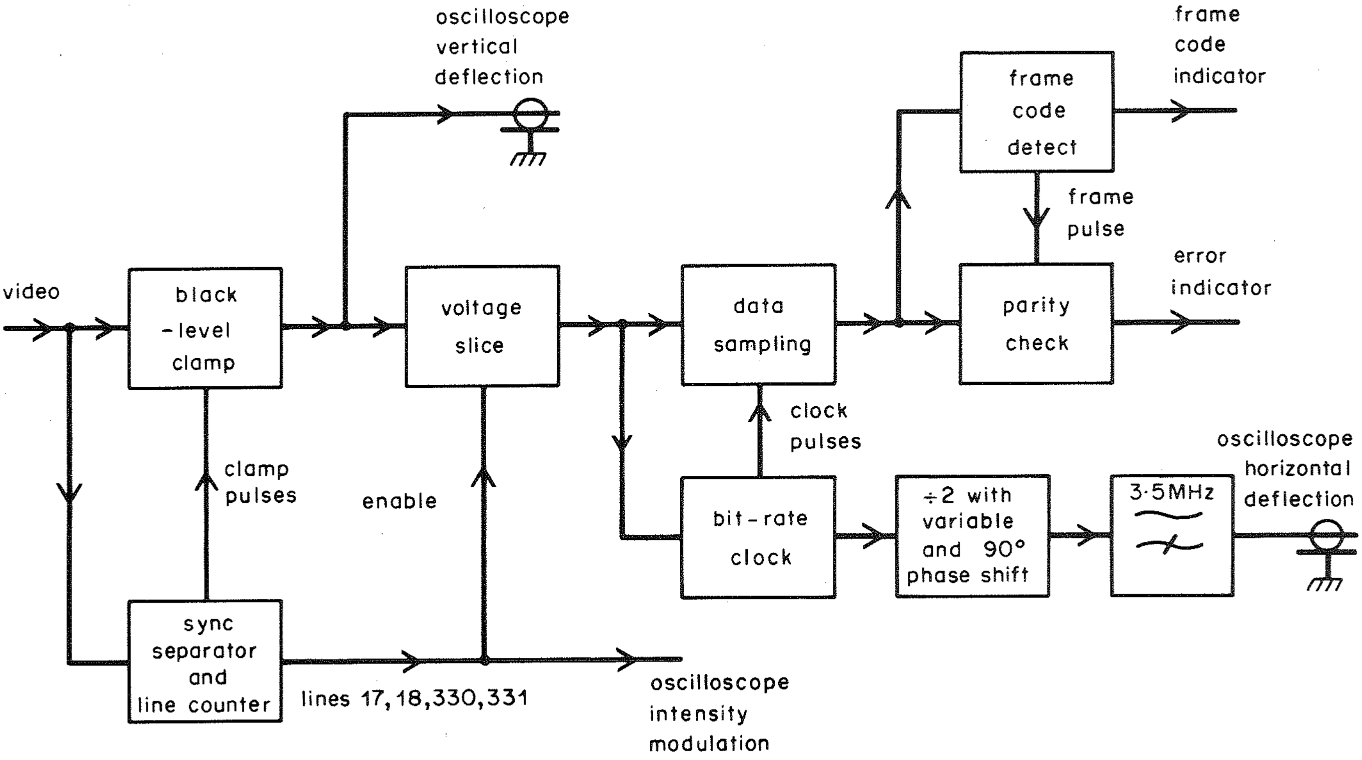


Fig. 6 - Schematic of eye display unit

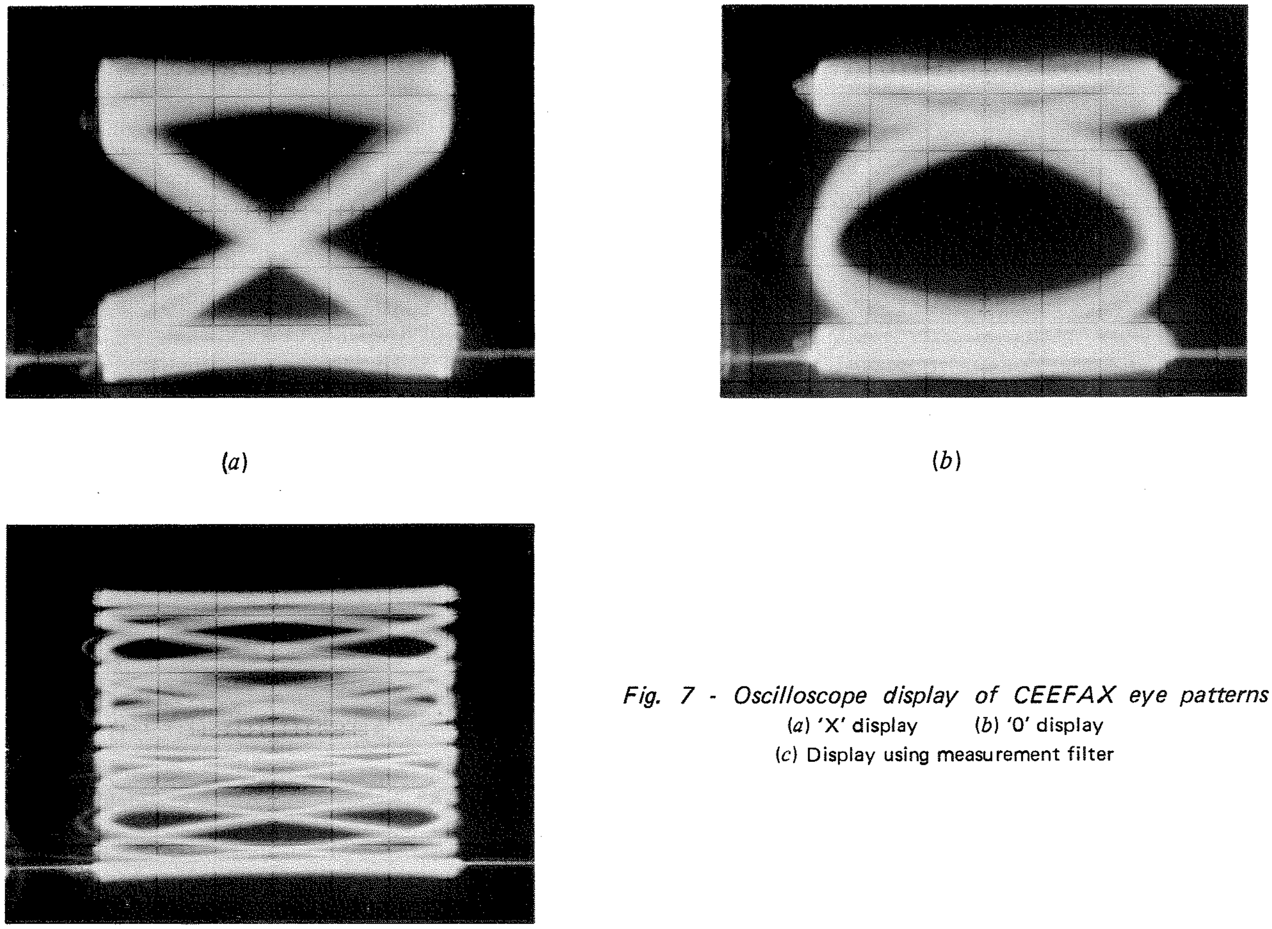


Fig. 7 - Oscilloscope display of CEEFAX eye patterns
(*a*) 'X' display (*b*) '0' display
(*c*) Display using measurement filter

An intensity modulation signal is generated so that the display may be blanked when CEEFAX waveforms are not being displayed.

A clamped video signal is provided for connection to the vertical amplifier of the oscilloscope.

5.2.2. Schematic

A schematic of a CEEFAX eye display unit is shown in Fig. 6.

The video signal is first clamped and the CEEFAX waveform is voltage sliced by comparing it with a manually adjustable voltage. A bit-synchronous clock signal is then generated and its frequency divided by two. This signal is then low-pass filtered to provide a sine wave at half bit-rate frequency to drive the horizontal deflection circuits of an oscilloscope; circuits are also included to enable the phase of the deflection waveform to be varied continuously, and to enable a 90° phase shift to be inserted. Signals to blank the oscilloscope display except during lines 17, 18 and 330, 331 are derived from the sync separator and line counter.

Additional facilities are provided to indicate when frame codes are being correctly detected and when parity errors are detected in the voltage-sliced and sampled data waveform. These assist in adjusting the data slice voltage and provide an additional check on the CEEFAX waveform.

5.2.3. Operation

Oscilloscope displays similar to those shown in Fig. 7(*a*) ('X' display) and Fig. 7(*b*) ('0' display) can be obtained by adjusting the phase of the horizontal deflection wave-

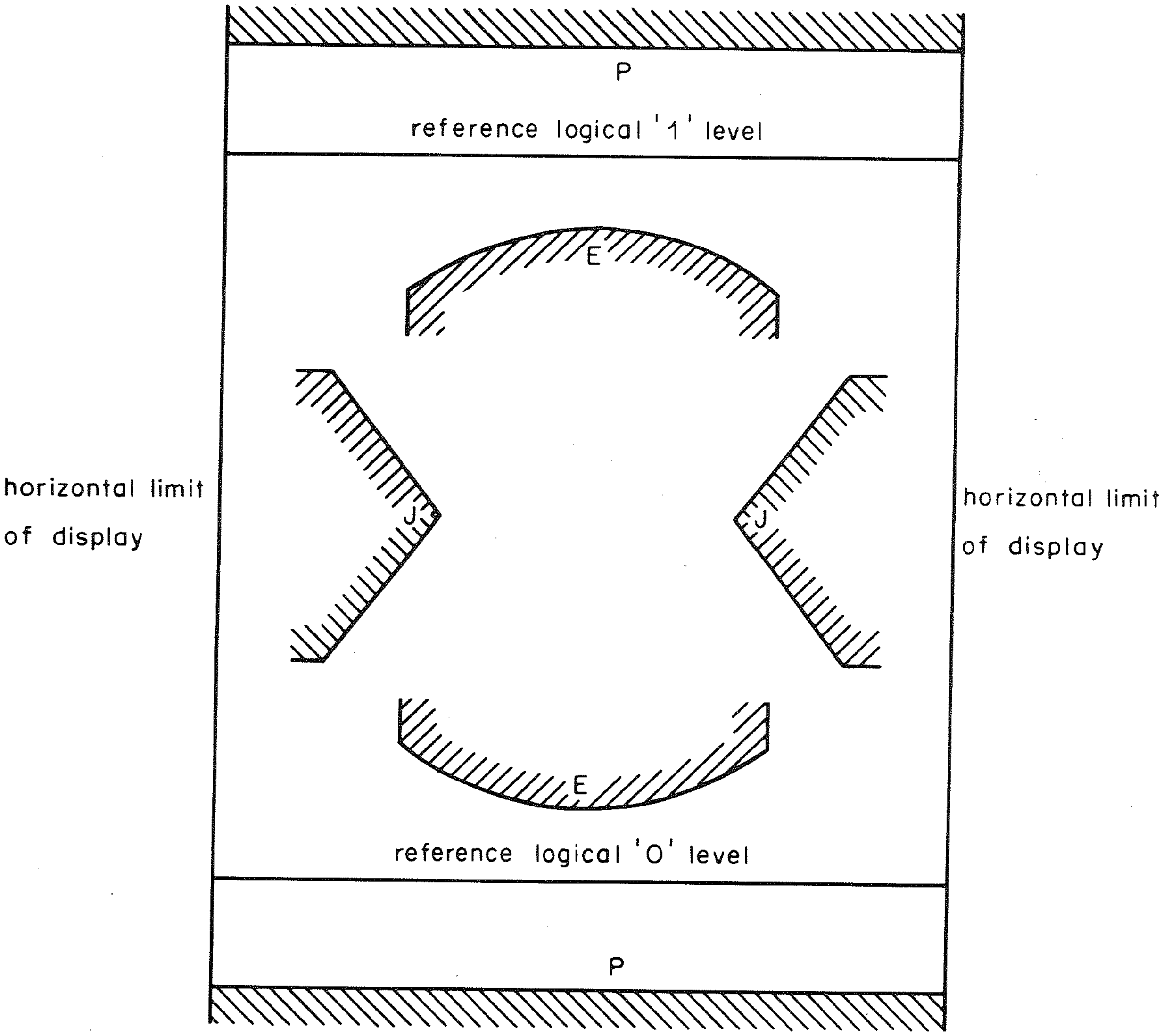

P
reference logical '1' level
E
horizontal limit of display
J
J
horizontal limit of display
E
reference logical '0' level
P

Fig. 8 - Example of a form of graticule for CEEFAX eye display
P — limit for overshoot, applies at all phases E — limit for eye, used with '0' display
J — limit for horizontal spread at centre of 'X' display

form. Switching the 90° phase change converts from one type of display to the other.

The variable phase control should be adjusted to minimise the horizontal spread in the centre of the 'X' display. In order to adjust the vertical gain of the oscilloscope a further display similar to that shown in Fig. 7(*c*) can be obtained by inserting a filter, as described in Section 2.3, in the video signal path between the eye display unit and the vertical amplifier of the oscilloscope; as already pointed out, this enables the reference logic levels to be established in the presence of noise and overshoots.

Measurements of eye-height can be made directly from the '0' display by observing the minimum height in the centre of the '0'. Care must be taken to include all traces no matter how infrequently they occur. Other measurements that can be made are the peak-to-peak magnitude of the data signal and the variations in the transition time from one state to the other (i.e. the horizontal spread at the centre of the 'X' display).

Alternatively these parameters could be compared with a graticule similar to that shown in Fig. 8 for simple acceptance testing of the signal.

5.2.4. Experience with eye display units

Prototype eye display units have been in use for some time. They have been used to check the CEEFAX waveform at points in the distribution network and have enabled those sections that cause the greatest distortion of the CEEFAX waveform to be identified. An eye display unit was also used during field tests in Bavaria.[3]

In practice it has been found difficult to make measurements of the normal CEEFAX waveform to an accuracy better than ±5%. This is because the content of the CEEFAX waveform varies considerably within one cycle of the CEEFAX magazine. Further, the presence of even quite small amounts of random noise makes the boundary of the eye pattern diffuse and difficult to measure.

5.3. An eye-height meter

5.3.1. Principle

An automatic eye-height meter* has been devised in which the data is applied to two voltage-slice circuits similar to those employed in decoders. In one the data is sliced by comparing it with the optimum slice voltage, in the other a perturbation wave is added to the same slice voltage. The outputs of both slice circuits are then sampled, using a bit-synchronous clock signal regenerated from the output of the unperturbed slice circuit, and the samples are then compared. Measurements are made of the level of the perturbing wave that can be applied before the two sample streams differ.

In the prototype, the perturbing wave was digitally generated square wave. The level of the wave was gradually increased and the digital values corresponding to the appearance of errors in logic '1's and in logic '0's were stored separately. The difference between these two values was calculated and displayed.

The measurement cycle took about 10 seconds, the time being longer for signals with larger eye-heights.

5.3.2. Results

The results obtained with the eye-height meter were found to be consistent (±2%) when making measurements using pseudo-random data. However, when the data source was a CEEFAX magazine, large inconsistencies were noted. In particular, it was found that the measurement depended on the time, in the magazine cycle, when the measurement was complete.

5.3.3. Further development

The dependence of results on the data being transmitted was a severe operational disadvantage with the prototype eye-height meter. However, further development of the device should overcome this problem. For example, instead of using an arrangement whereby the perturbing wave increases from a low level and each measurement is independent, it might be advantageous to increase or decrease the level of the wave depending on whether or not the two detected data streams were equal during the previous measurement cycle. This would give a continuously changing display of the measured eye-height of the signal.

6. Measurement of CEEFAX performance of a signal path using special test signals

6.1. General

Where a television signal path can be isolated from the network, tests can be made to assess its CEEFAX performance using test signals specially designed for the purpose, rather than using the normal CEEFAX signal. In this way, problems arising from the variable content of the normal CEEFAX waveform can be avoided. Further, the test signals need not be limited to a few lines in each television field-blanking interval. As a result the measurement techniques can be simplified and observations of waveform distortions can be made more readily.

A further advantage of using dedicated test signals is that timing and level references can be included. Hence absolute and reproduceable measurements can be made; it is not necessary to use circuits for the regeneration of a bit-synchronous clock signal from the CEEFAX waveform.

Two types of dedicated test signal are to be discussed. In one case a data waveform is used which has some similarities to a CEEFAX waveform but includes reference signals such as a timing reference for strobing the data and a CEEFAX related pulse-and-bar signal for defining level. In the other case, isolated pulses are used and the CEEFAX

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* This apparatus was devised and constructed by R. Storey.

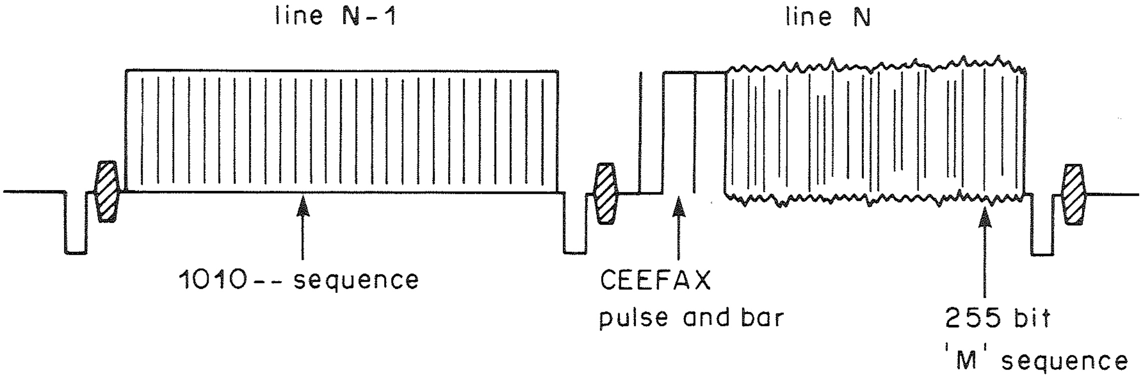

Fig. 9 - The data waveform test signal

performance of the signal path is computed from its response to the test pulse.

6.2. A data waveform test signal

6.2.1. General description

A signal generator has been developed* which generates data waveforms, including a pseudo-random sequence, for addition to the television signal during the period of one television line. During the previous line a wave at 3·46875 MHz is formed by a sequence of alternate logic '1's and '0's. With a very simple receiver, this signal, delayed by one television line period, can provide the horizontal deflection waveform for displaying the data eye pattern on an oscilloscope.

6.2.2. The generator

The waveforms generated for one pair of television lines are polarity reversed on alternate fields. The waveforms for one field are shown in Fig. 9.

A schematic of the generator is given in Fig. 10. Each component part of the waveform is generated as a logic waveform using a bit-rate clock locked to 444 times line frequency (6·9375 MHz). The pseudo-random sequence is generated using a feedback shift register.[4] The sequence is 255 bits long and contains all combinations of eight consecutive bits, hence only a few of the possible combinations of bit patterns found in CEEFAX are generated. However, in tests it has been found that the 255 bit sequence is adequate to give a meaningful result.

6.2.3. The receiver

A schematic of the receiver which generates an eye

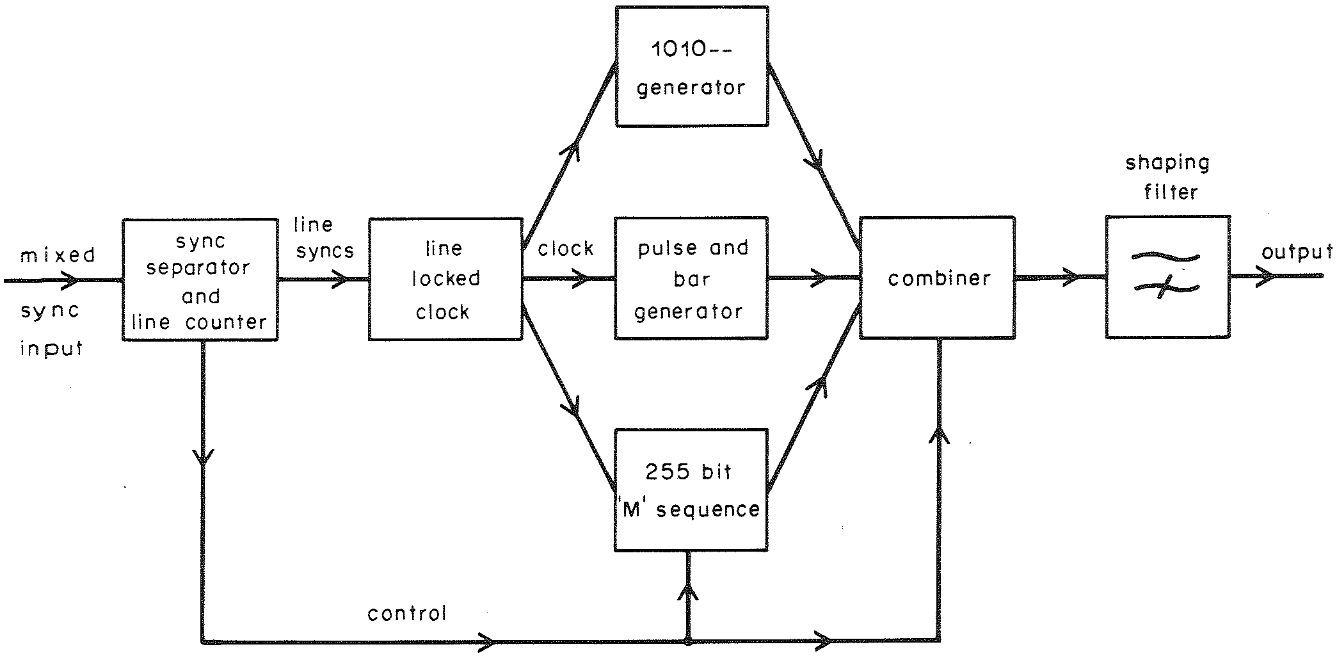

Fig. 10 - Schematic of data test waveform generator

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* The apparatus was devised by J.P. Chambers and J.R. Chew.

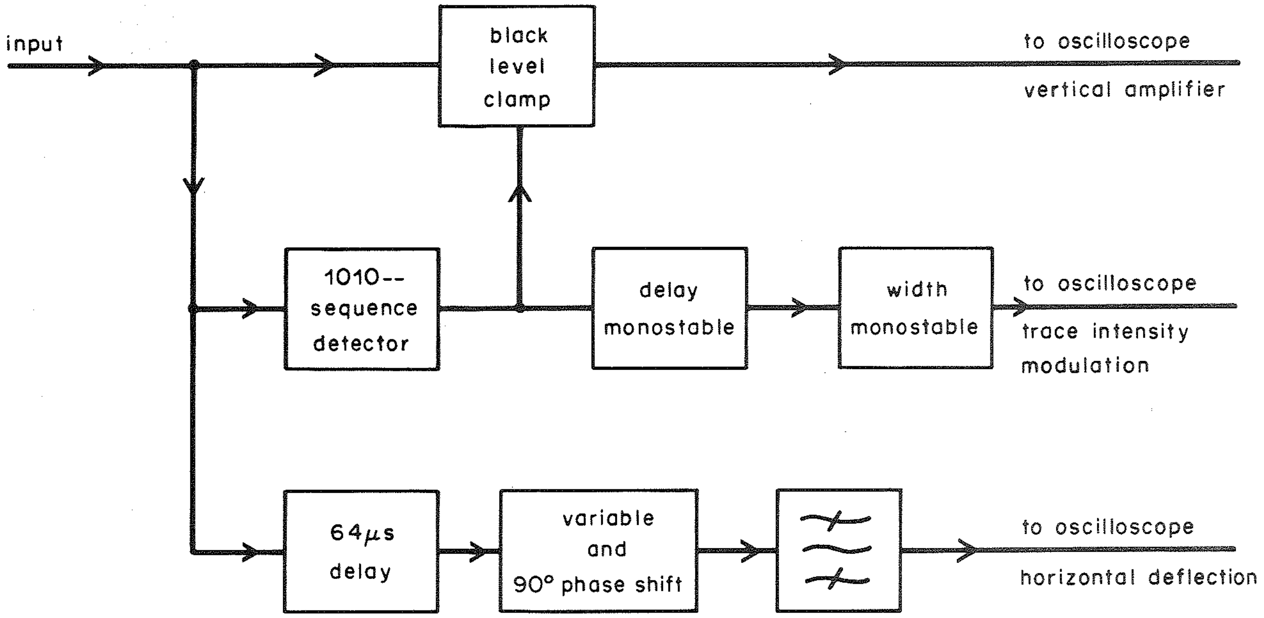

input
black level clamp
to oscilloscope vertical amplifier
1010-- sequence detector
delay monostable
width monostable
to oscilloscope trace intensity modulation
64µs delay
variable and 90° phase shift
to oscilloscope horizontal deflection

Fig. 11 - Schematic of data test waveform generator

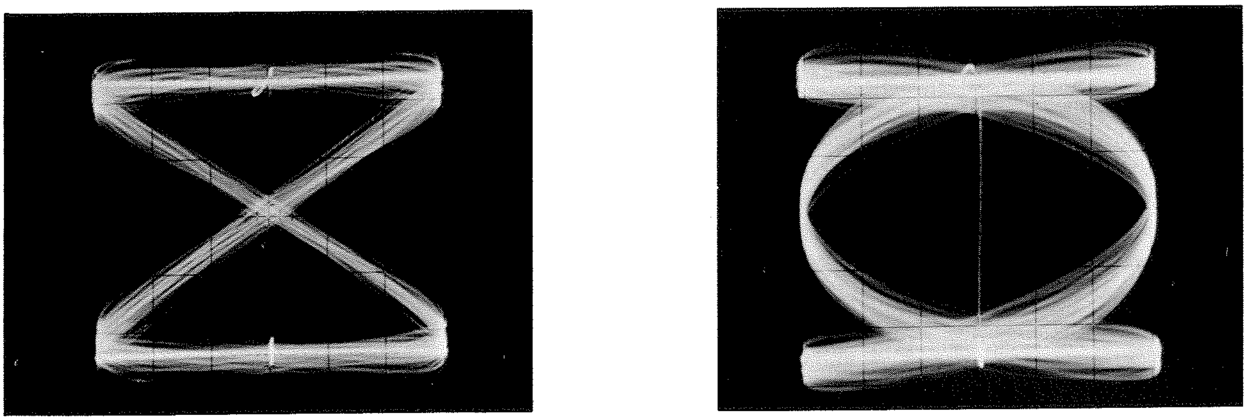
display on an oscilloscope is shown in Fig. 11. In the receiver, operations are initiated by detecting the 1010. . . . sequence on the first of a pair of lines occupied by the test signal: no sync. separator is required. The video signal is also d.c. clamped during this sequence.

An inexpensive chrominance delay-line, as used in domestic PAL colour television receivers, has been found suitable to give the 64 µs delay; the signal in this path is the narrow-band 1010. . . . sequence providing the horizontal deflection for the oscilloscope.

6.2.4. Operation

Photographs of eye displays produced using the generator and receiver are shown in Figs. 12(*a*) and (*b*); these are similar to the 'X' and '0' displays described in Section 5.2.3. However, in these cases the reference lines produced by the bar signals are clearly visible and can be used to determine the signal level.

Other useful displays that can be produced by triggering an oscilloscope so as to display portions of the test line are shown in Fig. 13(*a*) and 13(*b*). The display produced by superimposing the positive and negative CEEFAX pulses from alternate fields (Fig. 13(*a*)) gives an indication of the outer limits of the boundary of the eye; in practice, the eye will always be smaller than this. The data waveforms can also be examined to locate the data sequence that gives the smallest eye (Fig. 13(*b*)). For linear systems, the upper boundary of the eye will occur for the complement of the data sequence that produced the lower boundary of the eye. In Fig. 13(*b*) the delayed timing signal has also been displayed so as to indicate the centres



(*a*) (*b*)

Fig. 12 - Oscilloscope displays of eye using a data waveform test signal
(*a*) 'X' display (*b*) '0' display

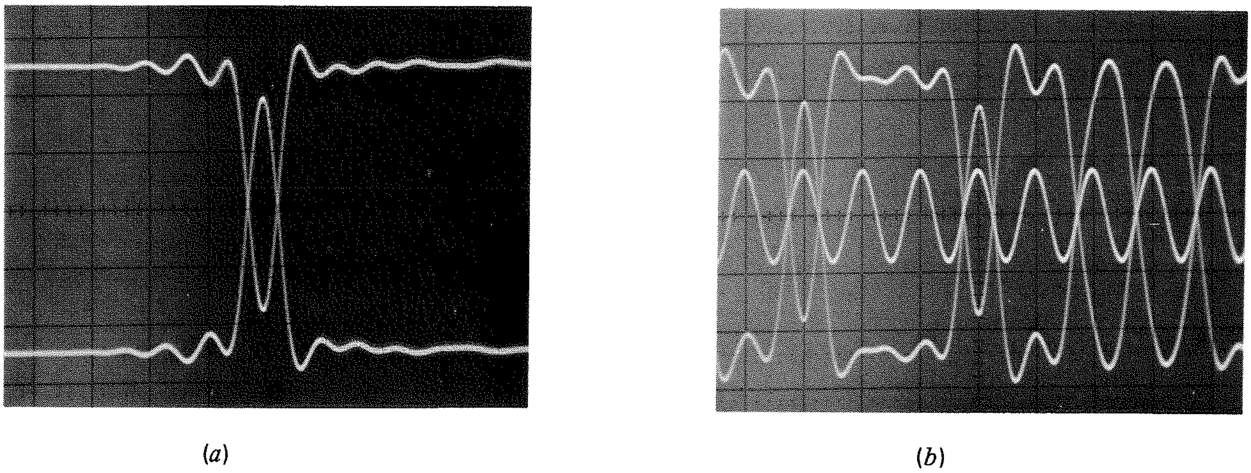

(*a*) (*b*)

Fig. 13 - Other oscilloscope displays of the data waveform test signal
(*a*) Positive and negative CEEFAX pulses (*b*) Superimposed data waveform and its complement

of the bit cells. This enables an accurate estimate to be made when the eye is limited by a data transition rather than an isolated pulse.

6.3. Computing CEEFAX performance from pulse responses

6.3.1. Using a 1T test pulse

Techniques for computing the CEEFAX performance of linear systems from their 1T pulse responses are described in Reference 5. The techniques described there involve digitising the reference pulse and the pulse response at the output of a system. Then, after procedures involving Fourier analysis and pulse-waveform reconstruction, the boundaries of the eye pattern can be recorded on a plotter.

6.3.2. Using a CEEFAX test pulse

The computations required using a 1T test pulse can be simplified if a CEEFAX pulse-and-bar is used as the test signal. It is then possible to make a fairly accurate prediction of the CEEFAX eye by making discrete measurements of the pulse waveform directly from an oscilloscope display.

In theory, a CEEFAX data waveform may be considered as the addition of separate waveforms each consisting of an isolated CEEFAX pulse. The amplitude of the CEEFAX waveform at a particular bit position is determined by the sum of the amplitudes, at that instant, of all the single pulse waveforms. This approach, which explains intersymbol interference, is further illustrated in Fig. 14, where, for simplicity, contributions from only three CEEFAX pulses are considered. In practice, there could also be contributions from other pulses affecting the portion of the waveform shown.

From this representation of the CEEFAX waveform it can be seen that the eye-height of a linear system can be predicted given the values of the systems response to a single CEEFAX pulse in the centre of each bit-cell. The lowest value '1' for the worst case data-sequence is given by the height of an isolated CEEFAX pulse less the sum of all the negative intersymbol components. The highest value '0' is given by the sum of all the positive intersymbol components. Hence the eye-height is given by the height of an isolated CEEFAX pulse less the sum of the moduli of all the possible intersymbol components.

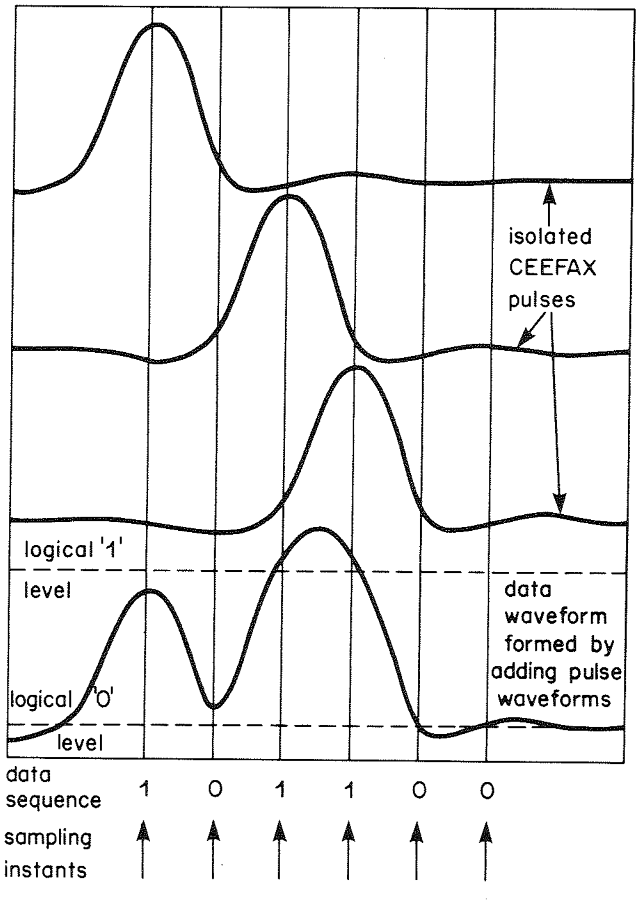
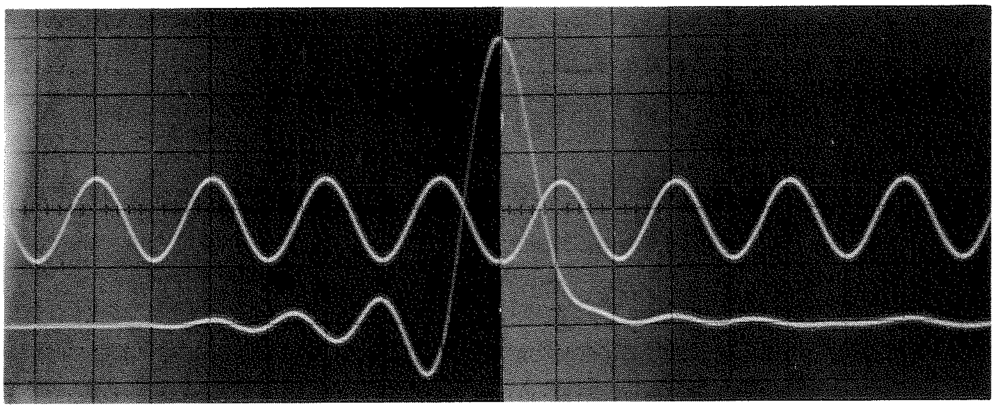
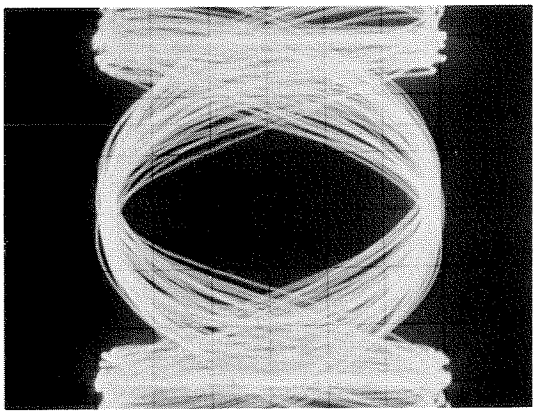


Fig. 14 - Construction of a CEEFAX waveform for the sequence 101100 from single isolated CEEFAX pulse waveforms



(*a*)



(*b*)

Fig. 15 - Estimating CEEFAX eye-height for a system from the intersymbol components of an isolated CEEFAX pulse

(*a*) A CEEFAX pulse response
Pulse height = 5·08 units
Bar height = 6·10 units
Sum of moduli of intersymbol components = 2·22 units

$$\text{Estimated eye-height} = \frac{5{\cdot}08 - 2{\cdot}22}{6{\cdot}10} = 47\%$$

(b) Eye display of same circuit

$$\text{Eye-height} = \frac{2{\cdot}90}{6{\cdot}10} = 48\%$$

This technique is illustrated in Fig. 15(*a*). Here the CEEFAX pulse-and-bar used was that generated by the apparatus described in Section 6.2. The timing reference wave generated by this apparatus was used to determine the centres of the bit cells taking the peak of the CEEFAX pulse as the centre of one bit cell. For comparison a photograph of the eye pattern is also reproduced (Fig. 15(*b*)).

This technique can only be used for linear systems. Where non-linear distortion, such as quadrature distortion, is present the assumptions made in the single-pulse representation of the signal are not valid.

7. Further work

In addition to the further development of the techniques described in this report it is anticipated that other techniques will be developed, which are more convenient in practice. One possible development might involve the digitising of the waveform enabling the fairly complex operations involved to be performed more accurately.

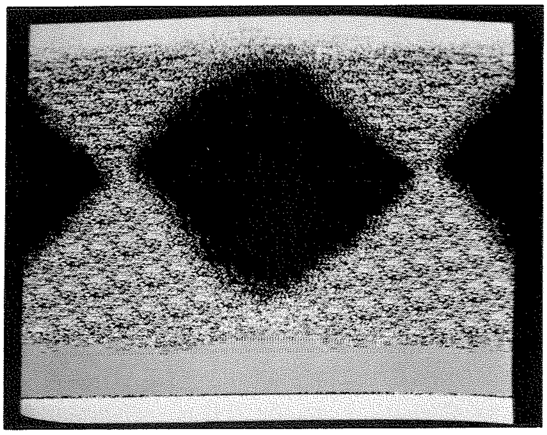


Fig. 16 - Simulated CEEFAX eye display on a television monitor screen

A further development of eye display techniques could be based upon a display on a television monitor screen. A system to do this has been simulated and the display obtained is shown in Fig. 16. In this simulation, data waveforms were added to all television lines. Two data slice circuits were used and, in the first the data was sliced using an optimum reference voltage and sampled at the optimum times. In the second circuit the slicing reference was perturbed linearly at field rate and the sampling rate, was off-set by twice line-frequency from the data rate. Differences between the two sample streams were used to modulate the intensity of the display.

The large display produced by this technique was found easier to observe than the oscilloscope displays of eye pattern outlined earlier in this report; it differs from the latter in that the horizontal time scale is linear and unidirectional, thus enabling the leading and trailing edge of the eye to be separated. However it was found necessary for the data source to be a long-length pseudo-random data sequence; otherwise certain data combinations were measured with only a few different slice voltages and sampling phases, which resulted in a constantly changing display. In practice, such a system would require storage of the error signals categorized in terms of reference voltage and phase. Nevertheless the experiment demonstrated the suitability of a television picture monitor for displaying CEEFAX eye patterns.

8. Conclusions

Techniques have been described which enable the CEEFAX waveform to be measured. Further, methods have been outlined which enable the CEEFAX performance of television signal paths to be predicted.

Most of the techniques currently in experimental use have been included. Some of these are not convenient to apply their present form but are being further developed.

9. References

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